Hetta Lake Subsistence Sockeye Salmon Project: 2007 Annual Report

by

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Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	$(F, t, \chi^2, etc.)$
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA REPORT NO. 09-34

HETTA LAKE SUBSISTENCE SOCKEYE
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ABSTRACT

Hetta Lake on Prince of Wales Island is a major sockeye salmon (*Oncorhynchus nerka*) producer in Southeast Alaska. The sockeye salmon run was, and continues to be, an important subsistence resource for Tlingit and Haida peoples. It also supported a large commercial fishery at the beginning of the 20th century. The run has declined to as little as one percent of former levels. Based on interviews of subsistence users in 2007, 3,178 sockeye salmon were harvested that year in Hetta Cove, the marine terminal area for Hetta Lake; the bulk of the harvest occurred between mid-July and mid-August. In 2007, the seventh year of monitoring of the sockeye salmon run in Hetta Lake, 12,860 sockeye salmon were counted at the Hetta Creek weir. The mark-recapture estimate, which was calculated to validate the weir count, was rejected due to violation of assumptions; the confidence interval for the rejected estimate included the weir count.

Key words: sockeye salmon, *Onchorynchus nerka*, subsistence, Hetta Lake, Hydaburg, Prince of Wales Island, escapement, mark-recapture, harvest census, zooplankton

INTRODUCTION

The Hetta Lake system on southwestern Prince of Wales Island was, historically, one of the most important sockeye-producing areas in Southeast Alaska. The system, consisting of the lake with inlet and outlet streams, drains into Hetta Cove, which joins with Hetta Inlet (Figure 1). Sockeye salmon (*Oncorhynchus nerka*) entering Hetta Lake spawn in the main inlet stream and along beaches adjacent to several short steep streams around the lake.

The system was an important source of subsistence sockeye salmon for the nearby Tlingit and Haida settlements. By the end of the 19th century, Hetta Inlet was also a commercially important sockeye salmon fishing area, with peak harvests of 140,000 to 250,000 fish in the 1890s (Moser 1899). Hydaburg, which developed into a commercial fishing community and is located about 17 km northeast of Hetta Lake, was consolidated from several surrounding Haida communities in 1911 (Betts et al., *in press*). The Hydaburg Cooperative Association operated a commercial sockeye salmon cannery there for a number of years. An historical summary of native settlements in this area and their reliance on sockeye salmon as well as the decline of the run, possibly from commercial fishing, can be found in Cartwright et al. (2005).

Subsistence fishing for sockeye salmon is still very important to the Hydaburg community, where 80 to 90% of households use this resource (Betts et al., *in press*). In addition to subsistence fishing, a mixed-stock commercial purse seine fishery takes place in Hetta Inlet and Cordova Bay. Some of these commercially-caught sockeye salmon are undoubtedly of Hetta Lake origin, though the extent of the Hetta Lake sockeye contribution to commercial fisheries has not been extensively studied.

As evidenced by historic commercial fishery catches, the Hetta Lake system supported a much larger sockeye run, possibly in the hundreds of thousands of fish (Moser 1899). The Alaska Department of Fish and Game (ADF&G) operated a weir on the outlet stream of Hetta Lake between 1967 and 1971; annual weir counts ranged from 16,000 to 24,000 sockeye salmon (Table 1). To prevent further depletion of the Hetta Lake sockeye population, after the marked decline of the run over the past 100 years, it is now important to develop good baseline information of the current sockeye salmon run sizes and to understand their annual fluctuations. It is also important to understand the impact of modern-day subsistence fishing on the Hetta Lake run in order to maintain sustainable subsistence fishing opportunities for Hydaburg residents.

Table 1.–Historical sockeye salmon escapement counts from the Outlet Creek weir located on the outlet stream of Hetta Lake.

Year	Weir count
1967	24,164
1968	17,599
1969	16,202
1970	20,542
1971	15,779
—	—
1982	5,387

The Hetta Lake sockeye stock assessment project was started in 2001 with a cooperative agreement between ADF&G, Hydaburg Cooperative Association, and the U.S. Forest Service. The goals of the project were to obtain estimates of sockeye salmon escapement into Hetta Lake and subsistence harvest of this run. Other important goals were to estimate age, sex and length distribution of the spawning sockeye salmon, sockeye salmon fry populations, and the composition of lake zooplankton. Basic limnological data for the lake, such as light, temperature, and dissolved oxygen levels were concurrently collected.

Between 2001 and 2004, adult sockeye salmon estimates were obtained with mark-recapture sampling. In 2005, a weir was installed in the outlet creek to count adults entering the system. The mark-recapture sampling was consequently improved upon and used to validate the weir count.

Previous years' studies have shown very small sockeye salmon escapements, in the 2,000 to 3,000 fish range, between 2001 and 2005. That these low mark-recapture estimates of sockeye salmon were realistic was confirmed by a weir-to-spawning grounds mark-recapture estimate of 3,300 fish in 2005. The following year, 2006, saw an increase to 18,000 fish, comparable to the weir counts of the late 1960's (Table 1). However, we have evidence of a dramatic shift in the small pelagic fish populations in Hetta Lake. In 2001 and 2002, the beginning of the recent study period, sockeye salmon fry made up around 85% of the trawl survey catch, and three-spine sticklebacks (*Gasterosteus aculeatus*) made up the rest. By 2006, sockeye salmon fry were only one to 2 percent of the catch. (Jan Conitz, ADF&G biologist, Juneau, *personal communication*). Hydroacoustic estimates of all small fish in Hetta Lake remained roughly constant during this period (2001–2006). Evidently, the sockeye fry population decreased dramatically between 2001 and 2006.

As in previous years, the most important objectives of the Hetta Lake 2007 study were to obtain a reliable and complete estimate of sockeye salmon escapement into the lake and a complete subsistence sockeye salmon harvest census from all fishers in the Hydaburg community. The 2007 season was the third consecutive season of weir operation and the seventh year of mark-recapture sampling, done concurrently in 2004–2007 to corroborate the weir count. Sockeye salmon were sampled for age, sex, and length composition. Zooplankton were sampled monthly for species composition, density, and biomass from mid-May through mid-September.

OBJECTIVES

1. Survey all subsistence fishers on the fishing grounds or as they return to Hydaburg to determine the total sockeye salmon harvest from streams and bays near Hydaburg, including Hetta, Eek, Kasook, Klakas, and Hunter Bay.

2. Operate a weir on the outlet stream of Hetta Lake from about June 15 to September 30, to count as much of the Hetta Lake sockeye escapement as possible.

3. Estimate the escapement of sockeye salmon into Hetta Lake using mark-recapture methods, so that the estimated coefficient of variation is less than 10%.

4. Estimate the age, length, and sex composition of the Hetta Lake sockeye escapement.

5. Measure water column temperature and light profiles in Hetta Lake through the season. Estimate zooplankton species composition, size, abundance, and biomass.

METHODS

STUDY SITE

Hetta Lake (ADF&G stream no. 103-25-047, 55° 10.17' N 132° 34.03' W) is located on the southwestern side of Prince of Wales Island, at an elevation of 9.4 m. The lake has a surface area of 207 ha, a volume of 99.4 million m^3, a mean depth of 48.0 m and a maximum depth of 92.0 m. The Hetta Lake watershed is composed of spruce, cedar, and hemlock forest, much of which was logged in the 1950s. Three streams empty into Hetta Lake: Hetta Creek; the main inlet stream; and 2 minor streams, Old Hatchery Creek and Camp Creek. The outlet creek, on the west side, drains Hetta Lake into Hetta Cove, about 600 m away. There are 3 main sockeye salmon spawning areas in Hetta Lake: Hetta Creek, on the northeastern side of the lake; the lake shoreline areas on the east side of the lake; and on the southern side of the lake in front of Old Hatchery Creek. In addition to sockeye salmon, other fish species include pink (*Oncorhynchus gorbusha*), chum (*O. keta*), and coho (*O. kisutch*) salmon, cutthroat (*O. clarki*) and steelhead (*O. mykiss*) trout, Dolly Varden char (*Salvelinus malma*), three-spine stickleback, and cottids (*Cottus* sp.).

SUBSISTENCE HARVEST

To determine subsistence salmon harvest by species, fishing area, date, time duration, and fishing gear, technicians interviewed subsistence fishers from Hydaburg either on the fishing grounds or in the harbor after a fishing trip. This survey was a census, as the crew interviewed every party that fished and returned to Hydaburg. All fishing areas were included: Hetta Cove, Eek Inlet, Hunter Bay, Klakas, and Kasook Inlet. The total harvest by area was the sum of individual harvests in each area.

SOCKEYE ESCAPEMENT ESTIMATE

Weir Count

The aluminum bipod and picket weir was located on the outlet creek. It was 17 m wide with pickets spaced 4.5 cm apart at center. Fish passed through an opening in the weir into a 2.5 m x 1.25 m rectangular trap box constructed of aluminum channel and pickets. A field crew from the Hydaburg Cooperative Association operated the weir from June 6th to September 25th 2007. All fish captured at the weir were enumerated by species and released upstream of the weir. A subsample of the sockeye salmon escapement was sampled for age (using scale samples), sex, and length, and marked with fin clips for the mark-recapture study.
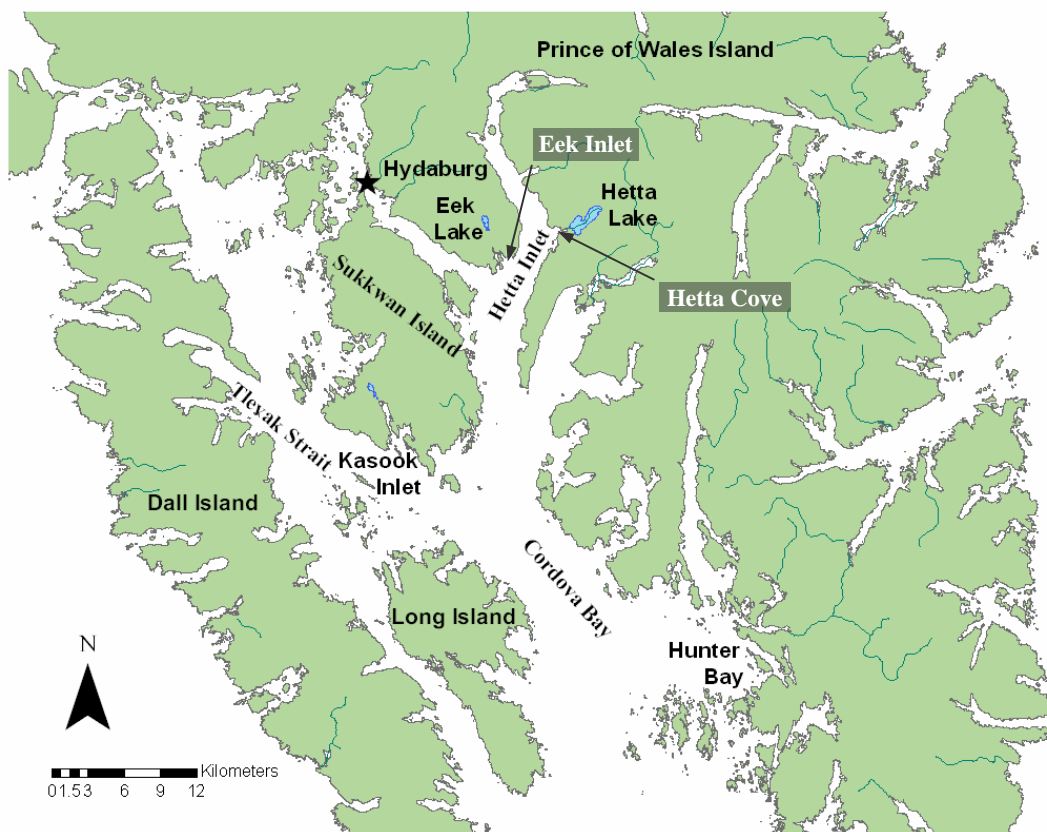
Figure 1.–The geographic location of Hetta Lake and subsistence fishing areas of Hetta Cove, Eek Inlet, Hunter Bay, and Kasook Inlet are shown in relationship to Hydaburg on southeast Prince of Wales Island.
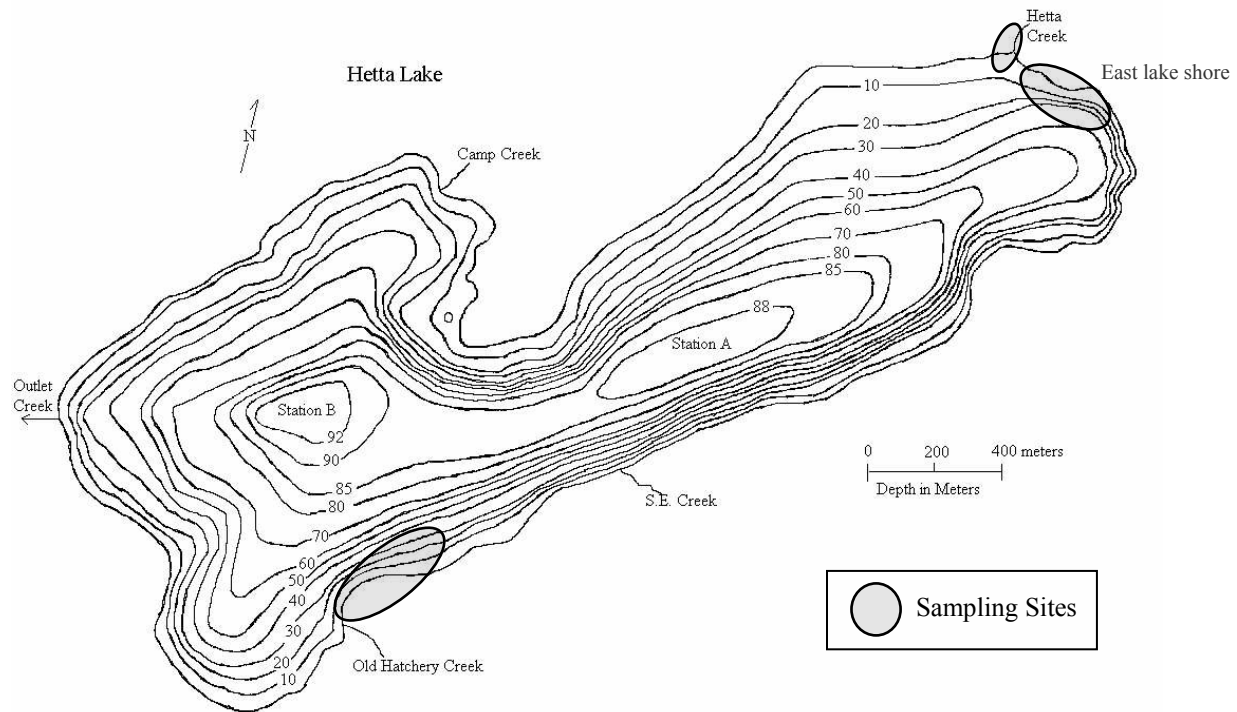
Figure 2.–Hetta Lake bathymetric map with locations of inlet and outlet streams, mark-recapture and visual counts sampling sites (Hetta Creek, east lake shore, and Old Hatchery Creek), and limnological sampling stations (A and B).

Mark-Recapture Estimate

Field Operations

In addition to the weir count, sockeye escapement into Hetta Lake was estimated using a mark-recapture study. The marking phase of the study was conducted at the weir. The mark-recapture estimate was a closed, 2-sample model with 3 temporal marking strata (Arnason et al. 1996). The marking strata were differentiated by changes in fin clips: June 6 to July 26 (adipose + dorsal); July 27 to August 10 (adipose + left pelvic); and August 11 to September 25 (adipose + lower caudal). The recapture phase on the spawning grounds was divided into 3 temporal-spatial strata: September 5 and 6 (Inlet Creek); September 11 (Inlet Creek); and September 25 to 26 (Inlet Creek, Old Hatchery Creek and east lake shore). Fish captured in these 3 strata were marked with 3 distinct opercular punches (left triangle, right triangle, and left square, respectively), to prevent duplicate sampling and thus ensure sampling without replacement.

Data Analysis

Mark-recapture sampling is a common way of estimating population abundance. The basic Peterson method involves marking a population subset of animals in the first stage and recapturing them at a later date in a second stage. The relationship of recaptured marked and unmarked animals in the second stage to the marked animals in the first stage provides a basic estimate of the population. Several assumptions need to be met for this sampling method to be

valid: both marked and unmarked animals have to have equal probabilities of capture in the first and second stages; and, marked and unmarked animals must mix freely.

A more sophisticated mark-recapture method that has been widely utilized for salmon escapement estimates involves separating marking and recapture phases into 2 or more temporal or spatial strata. Stratified mark-recapture estimates allow segregation of sampling, such as before and after a flooding event (temporal strata) or mark-recovery at different spawning locations (spatial strata). As with the simple Peterson method, the basic assumptions also apply to the stratified method. However, if one or more of these assumptions is met, the marking and recovery strata can be pooled together for a more precise estimate. If none of the assumptions are met, the strata should not be pooled, as the pooled estimate might be biased (Arnason et al. 1996).

We used Stratified Population Analysis System (SPAS) software (Arnason et al. 1996, http://www.cs.umanitoba.ca/~popan) to calculate the maximum likelihood estimates of Darroch and pooled Peterson (Chapman's modified), and their standard errors. SPAS was designed for analysis of 2-sample mark-recapture data where the first (marking) and second (mark-recovery) samples are collected over a number of strata.

We evaluated the validity of full pooling of marking and mark-recovery data (pooled Petersen estimate) using the first 2 chi-square tests provided in the software. These tests provide a reasonable indication of any serious violation of the basic mark-recapture assumptions by evaluating the following: 1) complete mixing of marked fish between release and recovery strata; and, 2) equal proportions of fish recovered from each marking stratum. A test statistic with p-value ≤ 0.05 was considered "significant." However, serious bias was indicated for the pooled Petersen estimate only if both test statistics were significant. If none or only one test statistic was significant, we accepted the pooled Petersen estimate.

If we rejected the pooled Petersen estimate, we evaluated the stratified Darroch estimate and attempted to find a reasonable partial pooling scheme, so as to reduce the number of parameters that needed to be estimated. To evaluate any partial pooling schemes, we used 2 additional goodness-of-fit tests for the Darroch estimate (provided in the SPAS software), along with the guidelines and suggestions from Arnason et al. (1996).

Visual Surveys

Crew members visually counted spawning sockeye salmon in all parts of the lake including Hetta Creek on September 3, 5, 11 and 25. Surveys of the lake perimeter were conducted by boat, and Hetta Creek was surveyed on foot, from the creek mouth to the barrier falls about one km upstream. Aside from September 3rd, all other visual counts were completed prior to a mark-recapture sampling event.

SOCKEYE ESCAPEMENT AGE AND LENGTH COMPOSITION

The field crew sampled 610 sockeye salmon for scales, length, and sex composition at the Hetta Lake weir and on spawning grounds. The number of fish sampled was close to the sampling goal of 620 sockeye salmon set before the season (Table 2). Scale samples were paired with sex and length data from each sample. Three scales were taken from the preferred area of each fish (INPFC 1963) and prepared for analysis as described in Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G Salmon Age Laboratory in Douglas, Alaska. Age classes were designated by the European aging system; freshwater years are counted after hatching and emergence from the gravel, and freshwater and saltwater years are separated by a period.

However, the total age is counted from the time the egg is fertilized, and adds one year to the sum of freshwater and saltwater years (from the European aging system). For example, a fish of age 2.3 spent 2 years in freshwater after hatching and 3 years in saltwater and was 6 years old when it returned to the lake to spawn (Koo 1962). The length of each fish was measured from mid-eye to tail fork to the nearest millimeter (mm). The proportion in each age-sex group was estimated along with its associated standard error, using standard statistical techniques assuming a binominal distribution (Thompson 1992).

Table 2.–Approximate weekly sampling schedule for sockeye salmon at the Hetta Lake weir in 2007 (length, sex, and scales).

Statistical Week	Dates	Sampling goal
24	June 10–16	0
25	June 17–23	10
26	June 24–30	10
27	July 1–7	20
28	July 8–14	20
29	July 15–21	40
30	July 22–28	60
31	July 29 –August 4	60
32	August 5–11	60
33	August 12–18	100
34	August 19–25	100
35	August 26–September 1	100
36	September 2–8	20
37	September 9–15	20
Total		620

LIMNOLOGY

Two fixed sampling stations were set at the 2 deepest parts of the lake basin, with anchored buoys demarcating their positions (Fig. 2). Station A was located at 55° 10.769′ N and 132° 33.474′ W and station B was at 55° 10.341′ N and 132° 33.526′ W. The sampling crew measured light and temperature, and collected zooplankton samples in Hetta Lake on May 21, June 20, July 19, August 14, and September 11, 2007. Light and temperature data were collected only at station B. Zooplankton samples were collected at stations A and B.

Light and Temperature Profiles

The sampling crew recorded underwater light intensity was recorded at 0.5-m intervals from just below the surface, to the depth where the ambient light intensity was 1% of that measured immediately below the surface light reading (the empirical euphotic zone depth) using an electronic light sensor and meter (Li-Cor). The natural log (ln) of the ratio of light intensity just below the surface to light intensity at depth z, I_0/I_z, was calculated for each depth. The vertical light extinction coefficient (K_d) was estimated as the slope of $\ln(I_0/I_z)$ versus depth. The euphotic zone depth (EZD) was defined as that depth at which light (photosynthetically available radiation at 400–700 nm) was attenuated to one percent of the intensity just below the lake surface (Schindler 1971) and was calculated with EZD = $4.6205/ K_d$ (Kirk 1994).

Temperature, in degrees centigrade (ºC), was measured with a Yellow Springs Instruments (YSI) Model 58 meter and probe. Measurements were made at 1-m intervals for the first 10 meters. Technicians would continue to measure at 1-m intervals if a discernable thermocline was present (defined as by temperatures decreasing at greater than or equal to 1ºC per meter), until temperature changes slowed to less than 1ºC per meter depth. Below 10 m or at the lower boundary of the thermocline, technicians would measure temperatures at 5-m intervals to 50 m depth.

Secondary Production

Sockeye fry typically feed on zooplankton, with a strong preference for *Daphnia* spp. when available (Scheuerell et al. 2005; Eggers 1982). To assess the quality of the prey base available to sockeye fry rearing in Hetta Lake, ADF&G technicians estimated zooplankton density and biomass by species or genus. A zooplankton sample was collected using a 1:3 conical net 0.5 m mouth diameter, 153 um mesh, at 2 stations. Technicians pulled vertical zooplankton tows from a maximum depth of 50 m, at a constant speed of 0.5 m·sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987).

At the limnology lab, each zooplankton tow was sub-sampled in the laboratory, according to specifications in Koenings et al. (1987). Technicians identified organisms to species or genus, counted, and measured organisms in the sub-samples,. Density (individuals per m^2 of lake surface area) was extrapolated from counts by taxon in the sub-samples. Seasonal mean density was estimated by taking the simple average of densities across sampling dates. The seasonal mean length for each taxon, weighted by density at each sampling date, was estimated and used to calculate a seasonal mean biomass estimate (mg·m^2 surface area) from known length-weight relationships (Koenings et al. 1987). Total seasonal mean zooplankton biomass and density were estimated by summing across all species.

RESULTS

SUBSISTENCE HARVEST

In 2007, 3,689 sockeye, 126 pink, 48 coho, and one chum salmon were harvested by subsistence users on fishing grounds around Hydaburg (Table 3). Eighty-three fishing parties logged over 350 hours fishing, mostly with seine nets, in Hetta Cove, Eek Inlet, and Klakas. Most of sockeye salmon (3,178 fish) were harvested in Hetta Cove, the marine terminal area for Hetta Lake; the bulk of the harvest occurred between mid-July and mid-August (Table 4).

Table 3.–Total 2007 subsistence salmon harvest on fishing grounds around Hydaburg, determined from fisher interviews.

Fishing locations	Interviews	Hours fished	Total subsistence salmon harvest			
			Sockeye	Coho	Chum	Pink
Hetta Cove	66	310	3,178	5	1	102
Eek Inlet	15	55	436	43	0	24
Klakas	2	15	75	0	0	0
Total	83	380	3,689	48	1	126

Table 4.–Sockeye salmon harvest rates by fishing area in 2007. Note that no subsistence fishing took place in Hunter Bay and Kasook.

DATES	Interviews	Hours Fished	Gear	Total Sockeye Subsistence Harvest		
				Per Interview	Per Hour	Per Week
Hetta Cove						
Jun 30–Jul 06	4	18	seine, gillnet	57	13	226
Jul 07–Jul 13	4	17	seine	41	10	162
Jul 15–Jul 20	11	42	seine	49	13	538
Jul 21–Jul 27	12	59	seine	70	14	843
Jul 28–Aug 03	11	51	seine	49	10	535
Aug 04–Aug 10	14	87	seine	42	7	588
Aug 11–Aug 17	5	17[1]	seine	33	10	164
Aug 18–Sept 1	5	19	seine	24	6	122
Total	66	293		45	10	3,178
Eek and Klakas						
Jul 21–Jul 27	3	5	seine	22	13	67
Jul 28–Aug 10	10	40	seine, dipnet	34	9	343
Aug 11–Aug 17	4	14	seine	25	7	101
Total	17	59		27	10	511
Grand Total	83	252				3,689

[1] Number of hours fished was not obtained from one of the interviews

SOCKEYE ESCAPEMENT ESTIMATE

Weir Count

Between June 06 and September 24, 2007, 12,860 sockeye salmon were counted at the Hetta outlet creek weir, as well as, 2,343 coho, 15,250 pink, and 296 chum salmon, and 11 Dolly Varden char. Due to concerns about flooding and a large accumulation of pink salmon, the weir was pulled mid-day on 25 September. There were still about 200 sockeye salmon below the weir. The sockeye salmon run passed the weir between August 28 and September 16, with 3 largest daily escapements occurring on August 31, 05, and September 15 (Figure 3).

Over the 4-month period of operation, the water depth level at the weir fluctuated between 0.32 m and 0.61 m, with 2 peaks on 11 July and 24 September.
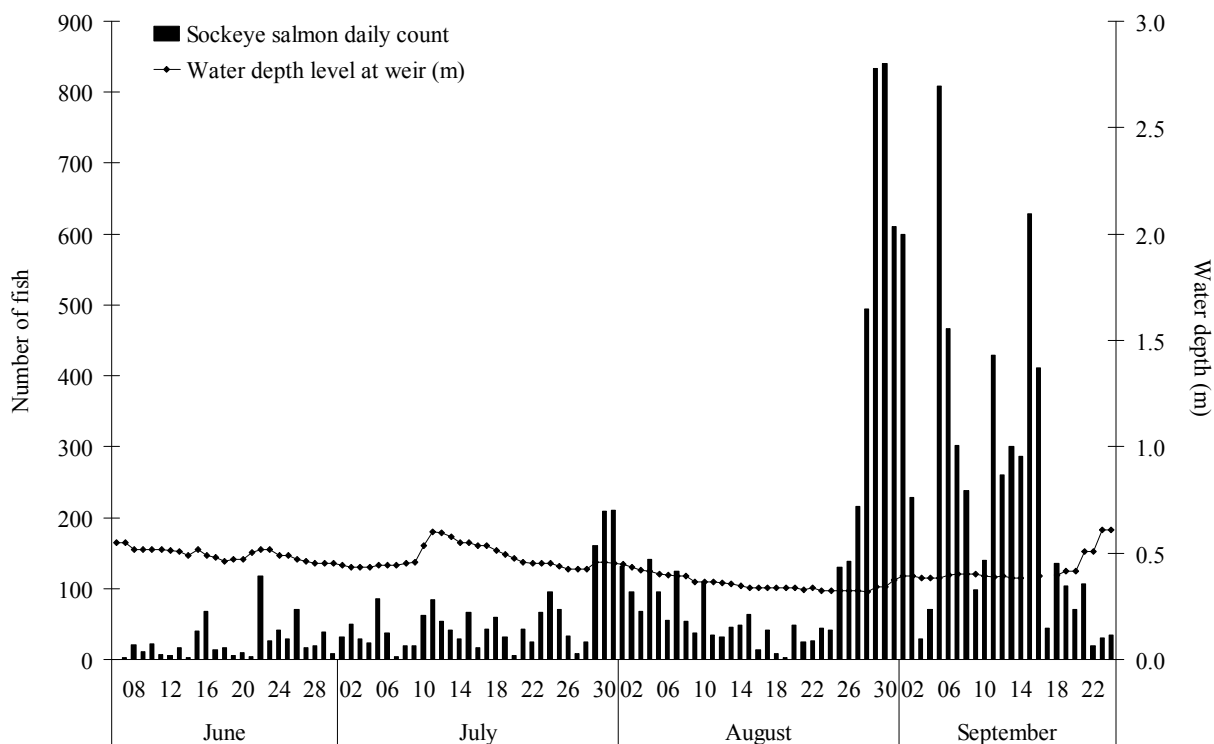
Figure 3.–Daily sockeye salmon escapement counts and water depth levels at the weir on Hetta Lake's outlet stream.

Mark-Recapture Estimate

Field Operations

In 2007, the weir crew marked a total of 3,791 sockeye salmon at the weir, in 3 temporal strata (Table 5). About 30% of fish were marked per stratum, which met our marking goal. However, marked fish recovery was uneven, with recovery rates for the different marking strata of 29%, 9%, and 1%. In addition to the temporal stratification imposed by marking, Hetta Lake sockeye salmon are also intrinsically stratified geographically by the spawning areas they seek out: stream spawners prefer inlet creeks, and beach spawners prefer areas along the lake shoreline. Beach spawners are the dominant group of the Hetta Lake sockeye run, and also have a later running time than the stream spawners. In 2007, our sampling opportunities dwindled as the fall progressed, because of increasingly bad weather conditions. In our recapture effort, the beach spawners were captured only in the last recovery stratum. The proportion of recovered (marked) beach spawners increased for successive marking strata, while the total number of tags recovered dwindled for successive marking strata. Overall, number of recovered (marked) beach spawners constituted no more than 3% of the number of fish marked within each marking stratum.

Table 5.–Sockeye salmon marked and marked fish recovered by strata in the mark-recapture experiment at Hetta Lake in 2007.

		Marking phase			Mark-recapture phase					
	Marking strata	Fish marked			Marked fish recovery by strata				% Stream spawners of total marked	% Beach spawners of total marked
				Fish weir count	1	2	3			
#	Dates	Number	Percent		Stream spawners	Stream spawners	Stream spawners	Beach spawners		
1	6/6–7/26	518	29.6%	1,748	59	37	37	15	25.7%	2.9%
2	7/27–8/10	465	30.5%	1,527	3	5	18	15	5.6%	3.2%
3	8/11–9/25	2,808	29.3%	9,585	0	1	7	7	0.3%	0.2%
Total		3,791	29.5%	12,860	62	43	62	37	—	—
Average			—	—	—	—	—	—	4.4%	1.0%
Total fish sampled					253	242	153	76	—	—
Perentage of marked fish					24.5%	17.8%	40.5%	48.7%	—	—

The chi-square statistics (in SPAS; Arnason et al. 1996), which tested for equal proportion of capture and for complete mixing, were significant ($p \leq 0.05$) for the stratified recovery data. The significance of these tests indicates a failure of the following assumptions: 1) all fish had equal chances of capture at marking and mark recovery; and, 2) mixing between the 2 phases was not affected by marking. Therefore, the pooled Petersen estimate was not used, due to significant potential bias. The Darroch maximum likelihood estimate for stratified data failed to converge. Based on our stated criteria and the failure of the assumptions, the mark-recapture experiment failed; we used the count from the weir as our estimate of escapement. Interestingly, the weir count fell within that the 95% confidence interval for the (rejected) pooled Petersen estimate.

Visual Surveys

In Hetta Lake, sockeye salmon spawn in at least 2 distinct groups. The stream spawners that use Hetta Creek were at peak numbers in early September. Numbers of beach spawners, those fish counted along the lake shoreline, increased later in September. However due to inclement weather, visual surveys ended prematurely in 2007, before majority of beach spawners began spawning; the beach spawners' peak number and date was not observed (Table 6).

Table 6.–Visual counts of stream and beach sockeye salmon spawners around Hetta Lake. Counts for Hetta creek were not made on 5 and 25 September.

	Stream spawners		Beach spawners		
Date	Hetta Creek	Hetta Creek mouth	East lake shore	Old Hatchery Creek	Total
3 Sept	81	98	0	0	179
5 Sept	197	—	0	0	197
11 Sept	350	100	34	0	484
25 Sept	114	—	98	110	322

SOCKEYE ESCAPEMENT AGE AND LENGTH COMPOSITION

The crew sampled 610 sockeye salmon for age, sex, and length composition. All 542 fish that were successfully aged were from brood years 2001 to 2004; the majority of the fish (85%) were age-1.3 from the 2002 brood year (Table 7). As expected, mean lengths of the fish corresponded with time spent in the marine environment. The age-classes 1.3 and 2.3 had roughly equal mean lengths (556 mm and 553 mm), while age-class 1.2 had a mean length of 484 mm (Table 8).

Table 7.–Age composition and proportion of sockeye salmon sampled between June 6 and September 25, 2007 at the Hetta Lake weir, by sex, brood year, and age class.

| | Brood Year | | | | | |
| | 2004 | 2003 | 2002 | 2001 | | All fish, |
Age	1.1	1.2	1.3	1.4	2.3	by sex
Males						
Sample size	29	2	242	3	22	298
Proportion of all fish	5.4%	0.4%	44.6%	0.6%	4.1%	55.0%
SE	1.0%	0.3%	2.1%	0.3%	0.9%	2.1%
Females						
Sample size	0	4	218	0	22	244
Proportion of all fish		0.7%	40.2%		4.1%	45.0%
SE		0.4%	2.1%		0.9%	2.1%
All fish, by age						
Sample size	29	6	460	3	44	542
Proportion of all fish	5.4%	1.1%	84.9%	0.6%	8.1%	
SE	1.0%	0.5%	1.5%	0.3%	1.2%	
Weighted proportion	3.0%	0.5%	89.9%	0.1%	6.5%	
Estimated escapement	391	61	11,561	17	830	

Table 8.–Length composition of sockeye salmon sampled between 6 June and 25 September 2007 at the Hetta Lake weir, by sex, brood year, and age class.

| | Brood Year | | | | | |
| | 2004 | 2003 | 2002 | 2001 | | All fish, |
Age	1.1	1.2	1.3	1.4	2.3	by sex
Males						
Sample size	29	2	242	3	22	298
Mean length (mm)	362	500	565	563	557	
SE (mm)	4.8	19	1.8	13.7	5.2	
Females						
Sample size	0	4	218	0	22	244
Mean length (mm)		473	545		548	
SE (mm)		5.4	1.5		4.8	
All fish, by age						
Sample size	29	6	460	3	44	542
Mean length (mm)	362	484	556	563	553	
SE (mm)	4.8	8.7	1.3	13.7	3.6	

LIMNOLOGY

Light and Temperature Profiles

The euphotic zone depth (depth at which measured light intensity is 1% of that of the surface) varied from about 10 to 12 m at station B in Hetta Lake (Table 9). The thermocline was already forming when we began measuring temperature on 21 May (Figure 4). It was fully developed by 19 July.

Table 9.–Euphotic zone depths at station B in Hetta Lake in 2007.

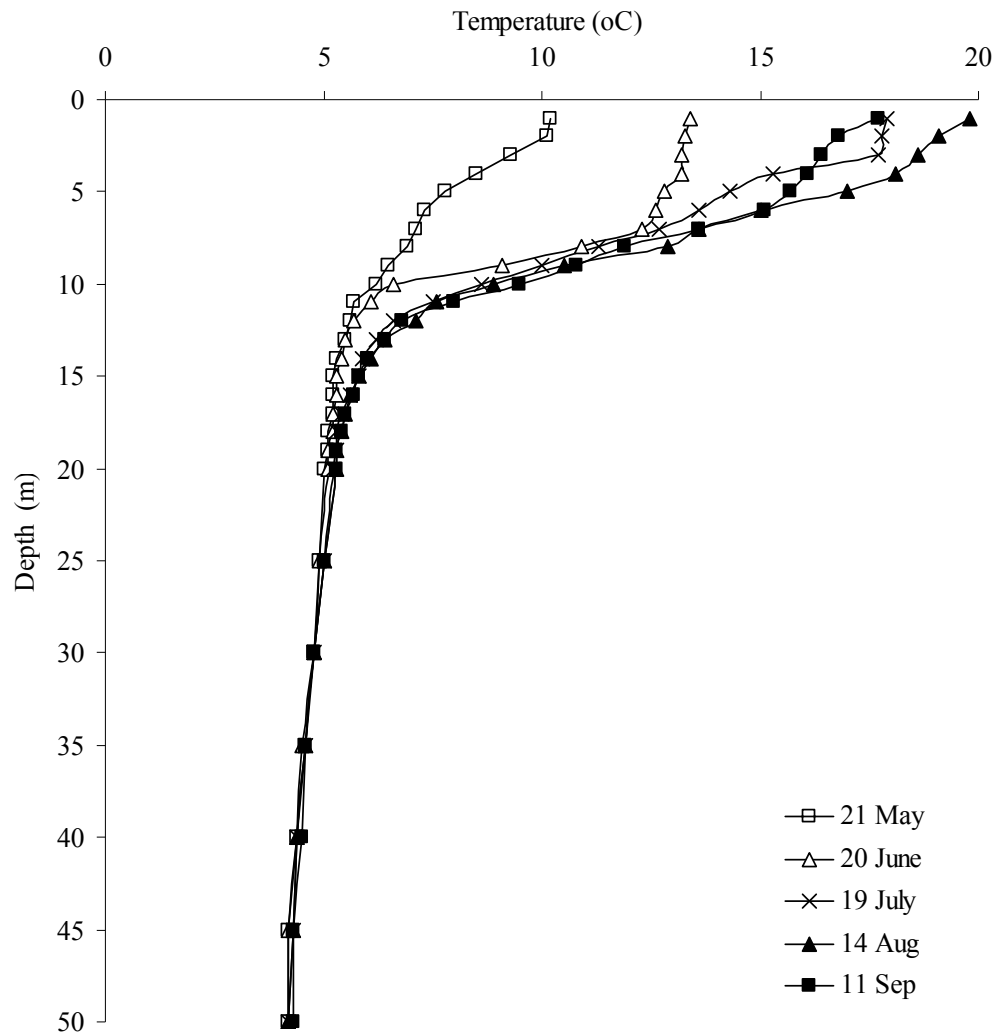| Date	Depth (m)
21 May	11.8
20 June	—
19 July	10.6
14 Aug	9.7
11 Sep	10.5
Seasonal mean	10.7

Figure 4.–Water temperature profiles at station B in Hetta Lake in 2007.

Secondary Production

Numerically, the dominant zooplankters present in Hetta Lake during the 2007 sampling period were *Bosmina* sp. (54%) and *Cyclops* sp. (17%; Table 10). We observed a steady decline in density of *Cyclops* sp. adults and nauplii, and an increase of *Bosmina* sp., over the sampling period. *Bosmina* sp. (62%) and *Cyclops* sp. (28%) were also the dominant zooplankton groups, in terms of biomass (Table 11).

Table 10.–Mean density of zooplankton, by sampling date and taxon, in Hetta Lake in 2007. Density estimates are averages of stations A and B.

Taxon	Mean density (number·m^{-2})				Seasonal mean	Percentage of seasonal mean total
	20 Jun	19 Jul	14 Aug	11 Sep		
Epischura sp.	0	64	64	0	32	0%
Cyclops sp.	10,910	10,316	7,917	2,229	7,843	17%
Nauplii	29,249	11,717	3,439	1,974	11,595	24%
Bosmina sp.	5,222	14,328	26,023	49,223	23,699	50%
Bosmina sp. (ovigerous)	85	509	4,903	1,847	1,836	4%
Daphnia longiremis	552	255	233	0	260	1%
Cladocera (immature)	425	1,656	4,585	2,929	2,399	5%
Total	46,443	38,844	47,164	58,202	47,663	

Table 11.–Seasonal mean length and biomass of zooplankton in Hetta Lake in 2007. Estimates are averages of stations A and B.

Taxon	Mean length (mm)	Seasonal mean biomass (mg•m^{-2})	Percentage of total biomass
Epischura sp.	1.23	0.8	3 %
Cyclops sp.	0.55	7.0	28%
Bosmina sp.	0.28	15.7	62%
Bosmina sp. (ovigerous)	0.43	1.4	5%
Daphnia longiremis	0.62	0.4	2%
Total seasonal mean biomass		25.2	

DISCUSSION

Compared to historical accounts (hundreds of thousands of fish harvested annually in the late 19th century; 15,000 to 20,000 fish in weir counts during the late 1960s), Hetta Lake sockeye escapements between 2003 and 2005 were very low, numbering around 3,000 fish. In the last 2 years (2006 and 2007), escapement counts were comparable to those of the late 1960s. The apparent increase in escapement is a good sign, but at minimum, several more years of monitoring are needed to determine whether these escapement levels are characteristic of the Hetta Lake system in its current state of productivity.

Subsistence harvest rates over the past 6 years appear to be stable, and reflective of the overall strength of the sockeye run. Not surprisingly, in years with higher sockeye salmon runs, more fish were harvested. Several areas around Hydaburg support sockeye salmon runs, and in years with reduced Hetta Lake sockeye returns, the subsistence fishing pressure was spread over those stocks, decreasing fishing pressure on the Hetta Lake run. A better understanding of the causes of low returns, and the range and timing of fluctuations of Hetta Lake sockeye salmon populations, is needed to determine the impact of subsistence fishing on the Hetta Lake stock. Trends in weir counts, mark-recapture estimates, and subsistence harvests show a qualitative correlation, and provide evidence of sockeye salmon escapement patterns over the past 7 years (Figure 5).
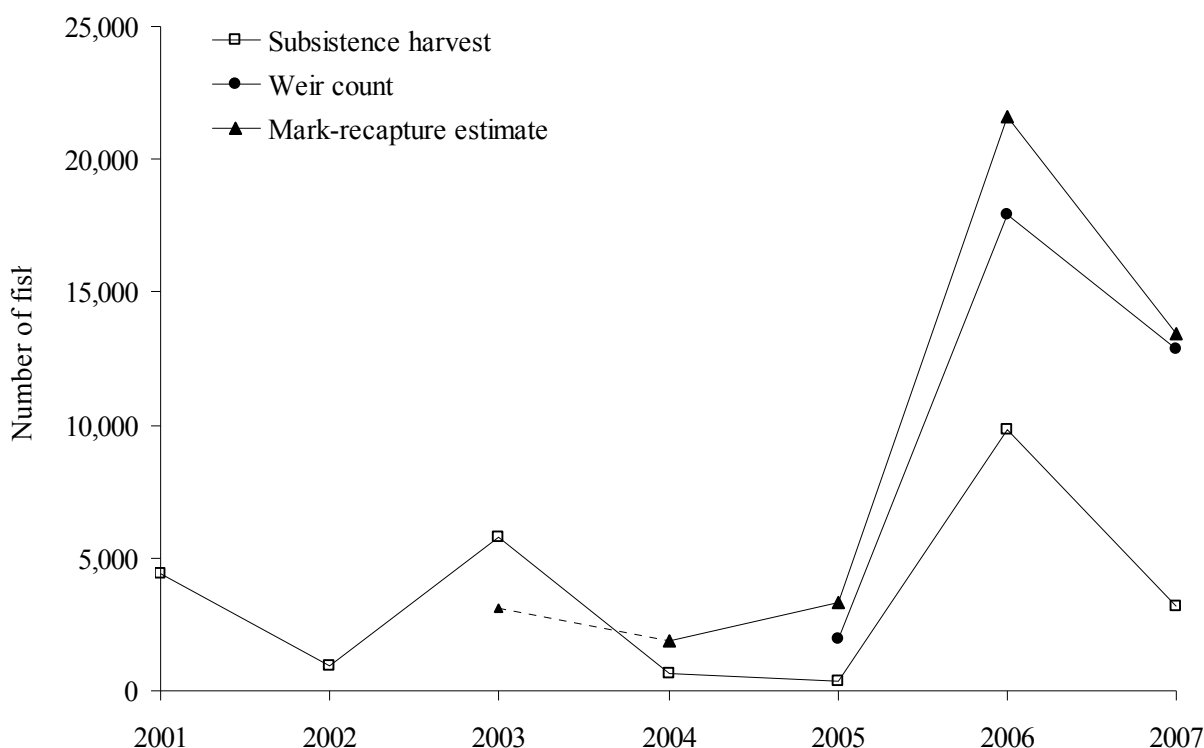
Figure 5.–Subsistence harvest and escapement estimates in Hetta Lake between 2001 and 2007. Dashed line indicates greater uncertainty in estimate.

A mixed-stock commercial fishery intercepting Hetta Lake and nearby sockeye salmon stocks can potentially influence the number of fish available to subsistence users and for spawning. No baseline data of commercially-harvested Hetta Lake sockeye salmon are currently available. However, methods such as the use of genetic markers, are being developed to determine the stock composition of commercially-harvested fish. In the future, ADF&G should be able to estimate commercial harvests from specific sockeye salmon stocks. If, at some point, the Hetta Lake sockeye run is deemed too small to sustain current subsistence harvests, the commercial harvest may need to be examined for its impact on escapement levels of the Hetta Lake stock.

Other important factors that may affect Hetta Lake sockeye runs include sockeye fry survival, the food quality and amount available to the fry, and potential competition for food by other

forage species. Due to weather conditions, hydroacoustic and trawl sampling of small pelagic fishes was not conducted this year. Previous years' studies showed a sharp decline in the proportion of sockeye salmon fry, coupled with a sharp increase of three-spine sticklebacks in trawl samples. In 2001 and 2002, sockeye fry were by far the dominant species in trawl samples. In 2003 and 2004, proportions of sockeye salmon fry and sticklebacks were roughly equal; after 2005, sockeye salmon fry apparently declined to a tiny percentage of the trawl catch (Conitz et al. 2008). This decline in the proportion of sockeye salmon fry to sticklebacks could be an indication of a shift in ecological conditions in Hetta Lake and, could affect the number of sockeye salmon smolts leaving the system. However, we also have reservations about the accuracy of the species composition estimates, and further work is needed to verify them.

Another potentially important factor affecting sockeye salmon fry survival is the quantity and composition of their prey. The total seasonal mean zooplankton biomass in Hetta Lake in 2007 (about 25 mg·m^{-2}) was even lower than in 2006, which had the lowest estimate of the 2001–2006 study period (Conitz 2008). The quantity of *Daphnia* in the total zooplankton assemblage may be a better indicator of food quality for sockeye fry (Mazumder and Edmundson 2002). In 2007, *Daphnia longiremis* comprised less than 2 percent of the total zooplankton biomass in Hetta Lake, far below levels observed in other sockeye-producing lakes in Southeast Alaska (Cartwright et al. 2005). As seen in previous years, the smaller zooplankters, *Bosmina* sp. and *Cyclops* sp., dominated the zooplankton assemblage in Hetta Lake.

ACKNOWLEDGMENTS

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APPENDICES

Appendix A.–Daily and cumulative counts of sockeye salmon, daily counts of other salmon species, and water depth and temperature at the Hetta Creek weir in 2006.

Date	Sockeye salmon		Other salmon, daily counts			Water depth (m)	Water temperature (^{o}C)
	Daily	Cumulative	Coho	Chum	Pink		
06 Jun	0	0	0	0	0	0.55	11
07 Jun	3	3	0	0	0	0.55	11
08 Jun	21	24	0	0	0	0.52	11
09 Jun	11	35	0	0	0	0.52	13
10 Jun	22	57	0	0	0	0.52	13
11 Jun	7	64	0	0	0	0.52	12
12 Jun	6	70	0	0	0	0.51	12
13 Jun	17	87	0	0	0	0.51	12
14 Jun	3	90	0	0	0	0.49	13
15 Jun	40	130	0	0	0	0.52	13
16 Jun	68	198	0	0	0	0.49	13
17 Jun	14	212	0	0	0	0.48	13
18 Jun	16	228	0	0	0	0.46	13
19 Jun	6	234	0	0	0	0.47	13
20 Jun	10	244	0	0	0	0.47	13
21 Jun	4	248	0	0	0	0.50	13
22 Jun	118	366	0	0	0	0.52	13
23 Jun	26	392	0	0	0	0.52	13
24 Jun	41	433	0	0	0	0.49	13
25 Jun	29	462	0	0	0	0.49	13
26 Jun	71	533	1	0	0	0.47	13
27 Jun	16	549	0	0	0	0.46	13
28 Jun	20	569	0	0	0	0.45	14
29 Jun	39	608	0	0	0	0.45	14
30 Jun	8	616	0	0	0	0.45	14
01 Jul	32	648	0	0	0	0.45	15
02 Jul	50	698	0	0	0	0.43	15
03 Jul	29	727	0	0	0	0.43	15
04 Jul	24	751	0	0	0	0.43	15
05 Jul	86	837	0	0	0	0.45	14
06 Jul	38	875	0	0	0	0.45	14
07 Jul	4	879	0	0	0	0.44	14
08 Jul	20	899	0	0	0	0.45	14
09 Jul	20	919	0	0	0	0.46	14
10 Jul	63	982	0	0	0	0.53	14
11 Jul	84	1,066	0	0	0	0.60	14
12 Jul	54	1,120	0	1	0	0.60	15
13 Jul	42	1,162	0	0	0	0.58	13
14 Jul	29	1,191	0	0	0	0.55	14
15 Jul	67	1,258	0	0	0	0.55	16

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Date	Sockeye salmon		Other salmon, daily counts			Water depth (m)	Water temperature (°C)
	Daily	Cumulative	Coho	Chum	Pink		
16 Jul	16	1,274	0	0	0	0.53	16
17 Jul	43	1,317	0	0	0	0.53	16
18 Jul	60	1,377	0	0	0	0.51	16
19 Jul	32	1,409	0	0	0	0.49	16
20 Jul	5	1,414	0	0	0	0.48	16
21 Jul	43	1,457	0	0	0	0.46	16
22 Jul	25	1,482	0	0	0	0.45	17
23 Jul	67	1,549	0	0	0	0.45	17
24 Jul	95	1,644	0	0	0	0.45	17
25 Jul	71	1,715	0	0	0	0.44	16
26 Jul	33	1,748	0	0	0	0.43	16
27 Jul	9	1,757	0	0	0	0.42	16
28 Jul	25	1,782	0	0	0	0.42	16
29 Jul	160	1,942	0	0	0	0.46	16
30 Jul	209	2,151	0	0	0	0.46	16
31 Jul	211	2,362	0	0	0	0.45	16
01 Aug	131	2,493	0	0	0	0.45	16
02 Aug	96	2,589	0	0	0	0.43	16
03 Aug	68	2,657	0	0	0	0.42	16
04 Aug	141	2,798	0	0	0	0.41	16
05 Aug	96	2,894	0	0	0	0.40	17
06 Aug	56	2,950	0	0	0	0.40	17
07 Aug	124	3,074	0	0	0	0.39	16
08 Aug	54	3,128	0	0	0	0.39	17
09 Aug	38	3,166	0	0	0	0.37	17
10 Aug	109	3,275	0	0	0	0.37	17
11 Aug	34	3,309	0	0	0	0.37	15
12 Aug	32	3,341	0	0	0	0.36	17
13 Aug	46	3,387	0	0	0	0.35	17
14 Aug	48	3,435	0	0	0	0.35	18
15 Aug	64	3,499	0	0	1	0.34	18
16 Aug	14	3,513	0	0	0	0.34	19
17 Aug	41	3,554	1	0	2	0.34	19
18 Aug	9	3,563	0	0	0	0.34	19
19 Aug	3	3,566	0	0	0	0.34	18
20 Aug	48	3,614	0	0	0	0.34	18
21 Aug	25	3,639	0	0	0	0.33	18
22 Aug	27	3,666	0	0	0	0.34	18
23 Aug	44	3,710	1	0	1	0.32	17
24 Aug	42	3,752	0	0	15	0.32	18
25 Aug	130	3,882	0	0	15	0.32	16

–continued–

Appendix A.–Page 3 of 3.

Date	Sockeye salmon		Other salmon, daily counts			Water depth (m)	Water temperature (^{o}C)
	Daily	Cumulative	Coho	Chum	Pink		
26 Aug	138	4,020	1	0	7	0.32	17
27 Aug	216	4,236	1	0	14	0.32	17
28 Aug	495	4,731	14	0	163	0.32	17
29 Aug	834	5,565	48	0	773	0.34	16
30 Aug	840	6,405	32	9	299	0.34	16
31 Aug	610	7,015	14	4	309	0.37	16
01 Sep	600	7,615	55	5	664	0.39	16
02 Sep	229	7,844	34	1	329	0.39	16
03 Sep	29	7,873	47	0	122	0.38	16
04 Sep	71	7,944	61	0	77	0.38	16
05 Sep	809	8,753	208	19	992	0.38	16
06 Sep	466	9,219	107	4	388	0.40	15
07 Sep	302	9,521	91	3	802	0.40	15
08 Sep	238	9,759	83	4	937	0.40	15
09 Sep	99	9,858	56	3	1136	0.40	15
10 Sep	140	9,998	63	8	856	0.39	16
11 Sep	429	10,427	106	9	1155	0.39	16
12 Sep	260	10,687	20	8	509	0.39	16
13 Sep	300	10,987	46	6	909	0.38	16
14 Sep	287	11,274	154	7	277	0.38	16
15 Sep	628	11,902	277	21	1067	0.00	16
16 Sep	411	12,313	123	25	607	0.39	16
17 Sep	45	12,358	14	5	119	0.00	15
18 Sep	136	12,494	28	14	500	0.40	15
19 Sep	104	12,598	19	16	502	0.41	14
20 Sep	70	12,668	45	25	407	0.41	14
21 Sep	106	12,774	259	43	603	0.51	13
22 Sep	20	12,794	85	17	179	0.51	13
23 Sep	31	12,825	103	13	196	0.61	14
24 Sep	35	12,860	131	12	258	0.61	13
Total	12,860		2,328	282	15,190		